RESEARCH DEPARTMENT

Long distance tropospheric propagation measurements over the North Sea at 560 Mc/s

REPORT No. K·163

1963/40

THE BRITISH BROADCASTING CORPORATION

ENGINEERING DIVISION

RESEARCH DEPARTMENT

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SUMMARY

This report presents the results of field strength measurements on horizontally polarized u.h.f. transmissions at 560 Mc/s over the North Sea at distances from 123 miles (198 km) up to 591 miles (950 km). These measurements extended over a period of two years and have been used in the preparation of field strength/distance curves for various percentages of the overall time. Measurements of site variation factor made within 1 mile (1·6 km) of the Happisburgh site indicate that the difference between the field strengths received at the Happisburgh site and the average site in the area depends upon the degree of abnormal propagation present.

The results are compared with earlier measurements at 187 Mc/s made over similar transmission paths and with measurements at 495 and 560 Mc/s made over land paths. It is revealed that signals are propagated over sea paths with considerably less attenuation in Band IV than in Band III. In Band IV there is less attenuation over sea paths than over land paths.

1. INTRODUCTION

Ultra high frequency transmitters situated in the United Kingdom and on the Continent of Europe may have to share the same channels. If the mutual interference between such common channel transmitters is to be kept to a minimum, reliable information concerning the propagation of u.h.f. over long sea paths must be available.

The experiment described in this report was made to obtain information concerning tropospheric propagation over sea paths in Band IV and followed earlier experiments[1,2] made over long sea paths on transmissions in Band II and Band III. This report presents the results of measurements made over a two-year period, from June 1959 to June 1961, of transmissions, on a frequency of 560 Mc/s, over the North Sea.

The results obtained during the period between June 1959 and November 1960 were presented for the Cannes (1961) Meeting of Experts of the CCIR.

2. TRANSMITTING AND RECEIVING SITE DETAILS

2.1. Transmitting Site

The transmitter was installed at Scheveningen Radio Station and was operated by the Netherlands Postal and Telecommunications Services. Site details are given in Table 1.

TABLE 1

Transmitting Site Details

TRANSMITTING SITE	SITE HEIGHT a.m.s.l.		AERIAL HEIGHT a.g.l.		LATITUDE	LONGITUDE
	ft	m	ft	m		
Scheveningen	43	13	155	47	52°06'N	04°16'E

The transmitter operated on a frequency of 560 Mc/s with horizontal polarization. The modulation, 100% square wave at a frequency of 1000 c/s, was cut for two seconds every minute to aid signal identification at the receiving sites. The transmitter radiated daily from 09.00 hours to 23.00 hours, British local time, until March 1961. After March 1961 transmission began at 08.30 hours.

The transmitting aerial, a two-stack Yagi, had an effective gain of 9·9 dB, relative to a $\lambda/2$ dipole, and gave an effective radiated power (e.r.p.) of 1·96 kW (mean) in the direction of maximum radiation, 320°E of True North.

2.2. Receiving Site Details

The receiving sites were those at which measurements were made during the Band II and Band III experiments.[1,2] Transmission paths of from 123 miles (198 km) to 591 miles (950 km) were provided. The geographical location of the sites is given in Fig. 1. The receiving aerials, double Yagis, were at a height of 30 ft (9·1 m) above ground level (a.g.l.). Details of the receiving sites are given in Table 2.

TABLE 2

Receiving Site Details

LOCATION	DISTANCE FROM TRANSMITTER		SITE HEIGHT a.m.s.l.		BEARING OF SITE FROM TRANSMITTER	LATITUDE	LONGITUDE
	miles	km	ft	m	°E of T.N.		
Happisburgh	123	198	50	15	295	52°49'42"N	01°31'38"E
Flamborough Head	227	365	150	46	309	54°07'39"N	00°05'40"W
Newton-by-the-Sea	338	543	70	21	317	55°31'06"N	01°37'05"W
Bridge of Don	429	690	30	9	326	57°10'40"N	02°05'00"W
Lerwick	591	950	300	91	342	60°08'00"N	01°10'20"W

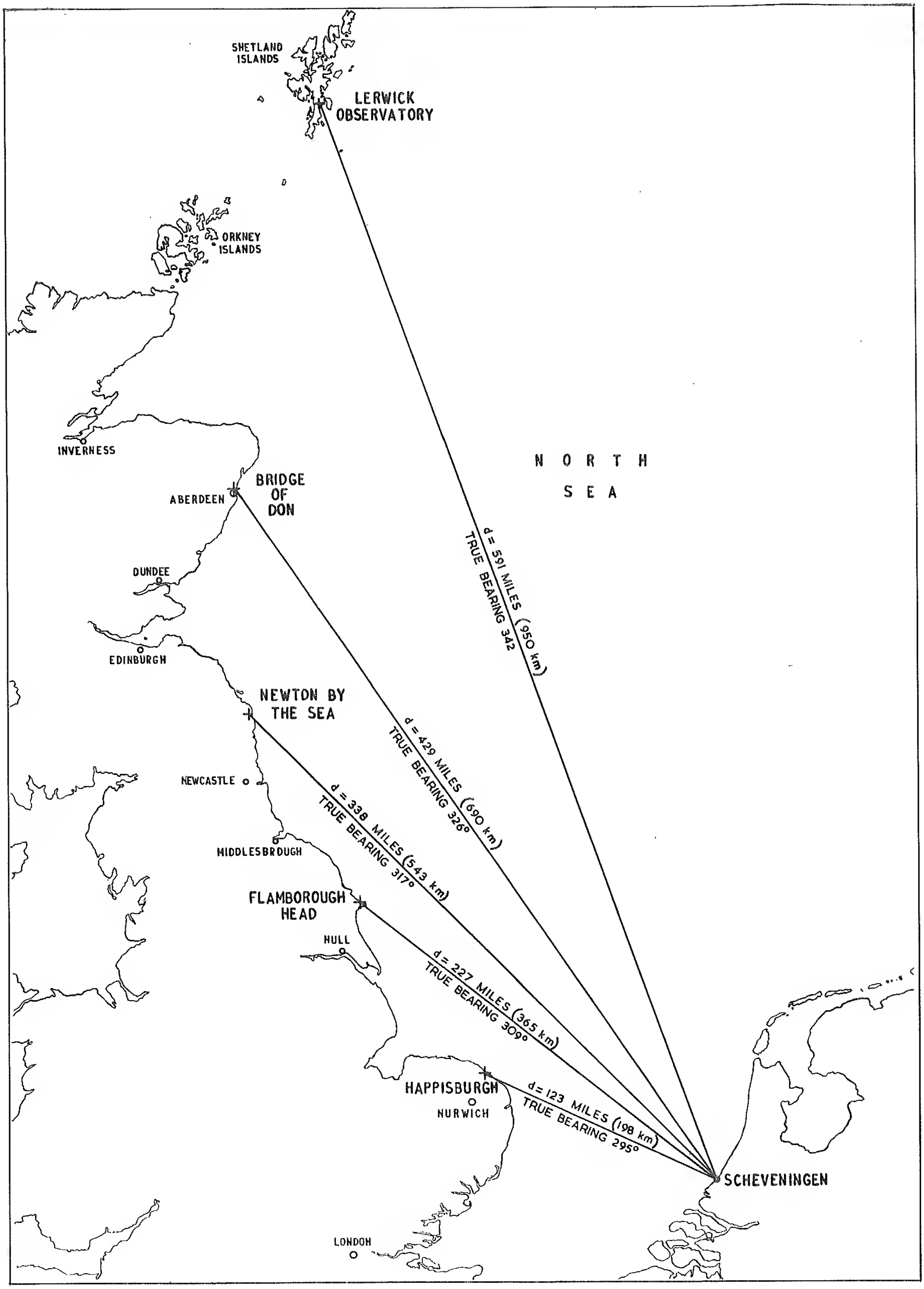

Fig. 1 - Geographical distribution of transmitting and receiving sites

● Transmitting site

✚ Receiving sites

The type of receiver installed has been described in detail in an earlier Research Department Report.[3] An approximately logarithmic recording law gives a signal range on a recording milliammeter of the order of 50 dB. This range is insufficient under certain conditions, and an attenuator is switched into circuit between the r.f. and i.f. units when the recording milliammeter reaches full scale deflection.

3. RESULTS

3.1. Analysis

The recording charts were run at speeds of 3 inches (7·6 cm) or 6 inches (15·2 cm) per hour depending on the type of signal normally received. Analysis consisted of determining the time during which the field strength exceeded certain fixed levels on the recording chart. The daily analysis was grouped into months, and the months were grouped to give the overall results.

3.2. Variations of Field Strength with Time at the Receiving Sites

The analysis of the measurements made is shown in Fig. 2 plotted as field strength against percentage valid recording time. At Newton-by-the-Sea the signals received were above receiver noise level for 8·5% of the time; the appropriate curve has been extrapolated in order to estimate a value of field strength exceeded for 10% of the time. No extrapolations have been made from the Bridge of Don or Lerwick results, with signals above noise level for 3·9% and 2·4% of the time respectively. Results for certain percentage times are given in Table 3.

TABLE 3

560 Mc/s Oversea: Measured Results

RECEIVING SITE	FIELD STRENGTH, dB rel. 1 μV/m FOR 1 kW e.r.p.				
	0·1%	1%	5%	10%	50%
Happisburgh	69·0	62·0	47·5	35·0	7·0
Flamborough Head	67·5	58·0	31·5	14·0	N.L.
Newton-by-the-Sea	60·0	44·0	10·0	-7·0*	N.L.
Bridge of Don	46·0	25·0	N.L.	N.L.	N.L.
Lerwick	47·0	21·0	N.L.	N.L.	N.L.

* Extrapolated

N.L. - Signal did not exceed receiver noise level for the appropriate percentage time.

Signals above free space field strengths were recorded at all sites for percentages of the time from 0·05% at Bridge of Don to 1·3% at Happisburgh. The close similarity between the curves in Fig. 2 for Bridge of Don and Lerwick for field strengths above 30 dB may be a result of the greater height above sea level of the more distant receiving site.

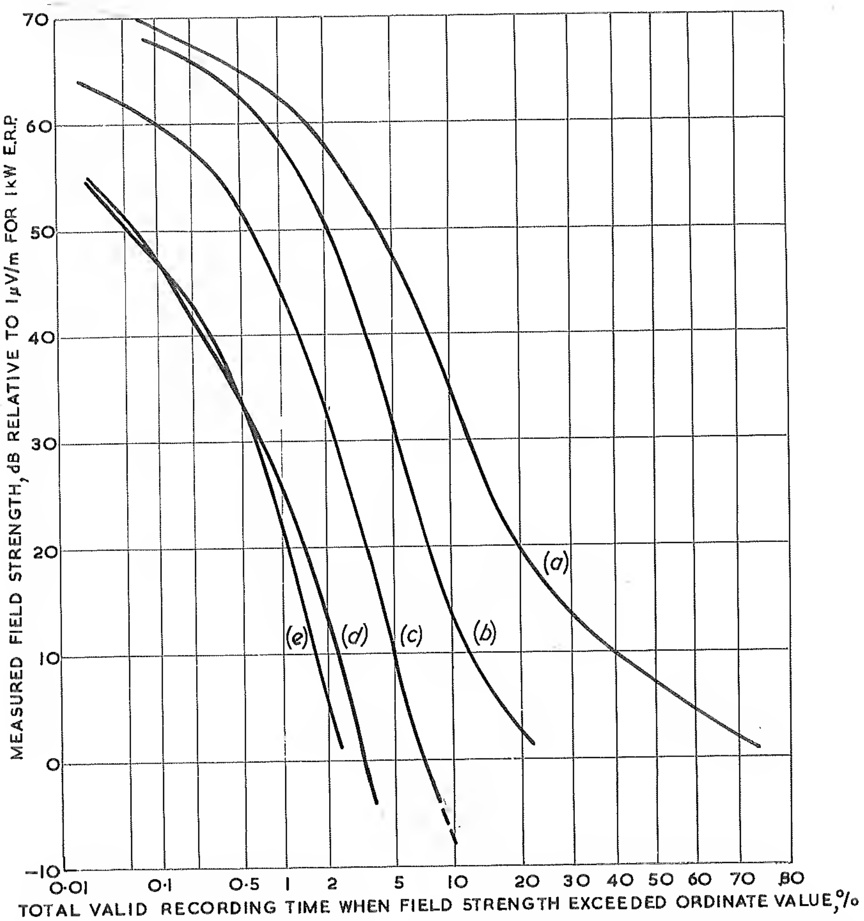

Fig. 2 - 560 Mc/s oversea: variation of field strength with time

Curve	Site	Distance Miles	Distance km	Total Hours Recorded	Free Space Field (dB)
(a)	Happisburgh	123	198	9336	61·0
(b)	Flamborough Head	227	365	9604	55·9
(c)	Newton-by-the-Sea	338	543	9025	52·2
(d)	Bridge of Don	429	690	9783	50·2
(e)	Lerwick	591	950	9697	47·3

3.3. Monthly Field Strength Variations

The field strengths recorded each month for certain selected percentages of the time have been plotted in Fig. 3 for each site. With the marked exception of January 1961, a seasonal pattern is suggested by the curves, with signals tending to be lower during the winter months. In January 1961 signals were recorded at all sites except Newton-by-the-Sea, where the receiver was unfortunately inoperative at this time.

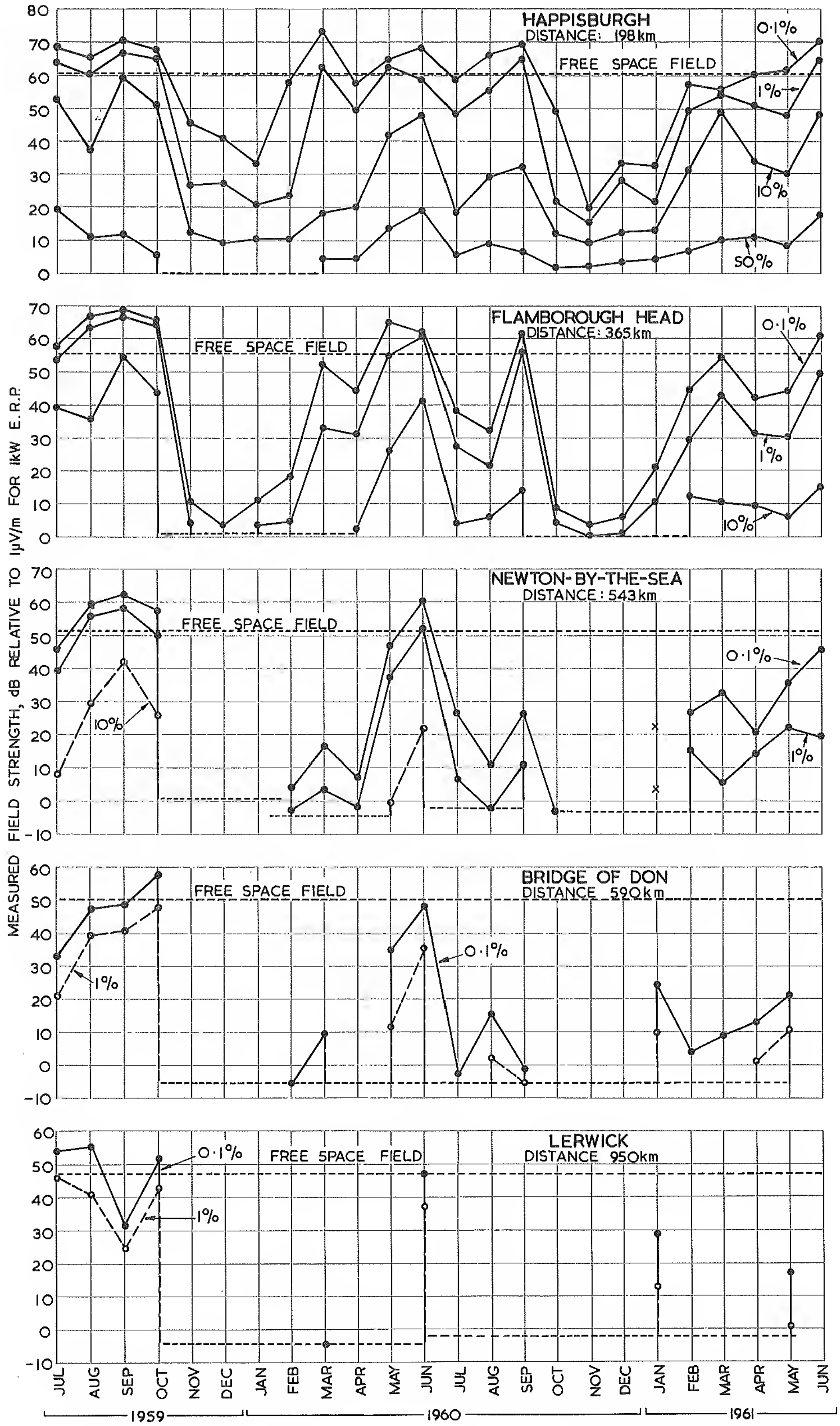

Fig. 3 - 560 Mc/s oversea: monthly variations in field strength

------- NOISE LEVEL

× RECEIVER INOPERATIVE

The prolonged summer of 1959 was particularly favourable for propagation, especially over the longer transmission paths. Table 4 is a comparison between the occurrence of signals in excess of free space for certain percentage monthly times in 1959 and the rest of the period.

TABLE 4

Band IV Oversea: Occurrence of Free Space Fields

RECEIVING SITE	PERCENTAGE TIME	NUMBER OF MONTHS WHEN FREE SPACE FIELDS WERE EXCEEDED FOR STATED % TIME	
		JULY/DECEMBER 1959	JANUARY 1960/JUNE 1961
Happisburgh	1%	4	4
Flamborough Head	1%	3	3
Newton-by-the-Sea	1%	2	1
Bridge of Don	0·1%	1	0
Lerwick	0·1%	3	1

3.4. Daily Field Strength Variations at Newton-by-the-Sea

Field strength/percentage time curves were drawn for each day's recording at Newton-by-the-Sea and from these the curves plotted in Fig. 4 have been derived. Fig. 4(a) shows the number of hours per day that the recorded signal exceeded certain fixed levels of field strength and Fig. 4(b) shows the field strength exceeded for various durations daily, both plotted against their occurrence during the two-year period. These curves show in some detail the distribution of occurrence of the high field strengths received, and may assist in assessing permitted co-channel interference limits. For example, a field strength of 10 dB relative to 1 μV/m for 1 kW e.r.p., although exceeded for only 5% of the total time, was exceeded during the two years of the experiment for at least two hours on 55 days and for at least eight hours on 22 days.

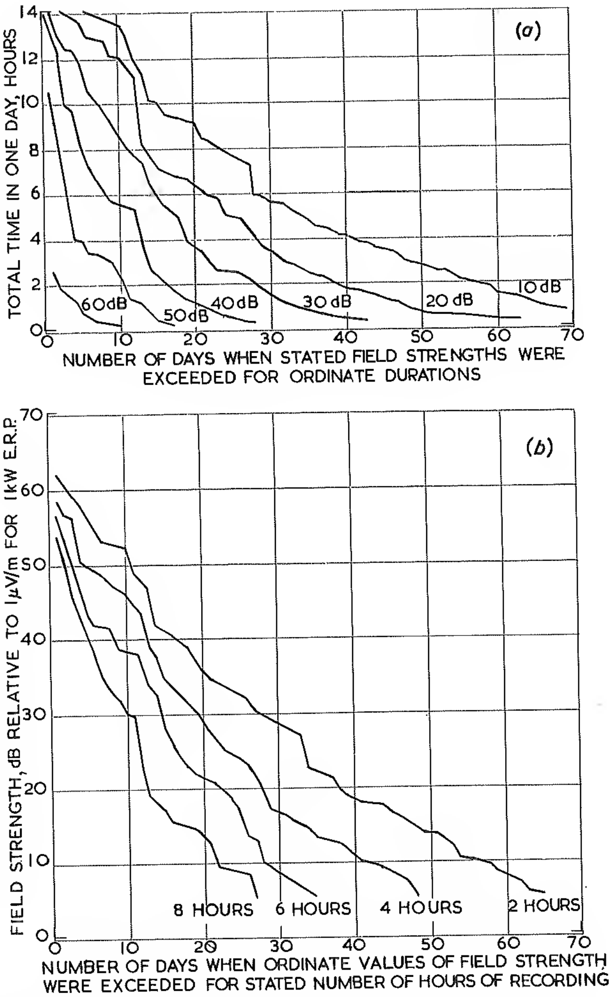

Fig. 4 - 560 Mc/s oversea: daily occurrence of signals at Newton-by-the-Sea

4. FIELD STRENGTH/DISTANCE CURVES

Field strength values for selected percentages of the time, listed in Table 3, have been plotted in Fig. 5 against distance on a logarithmic scale. Lines of best fit,

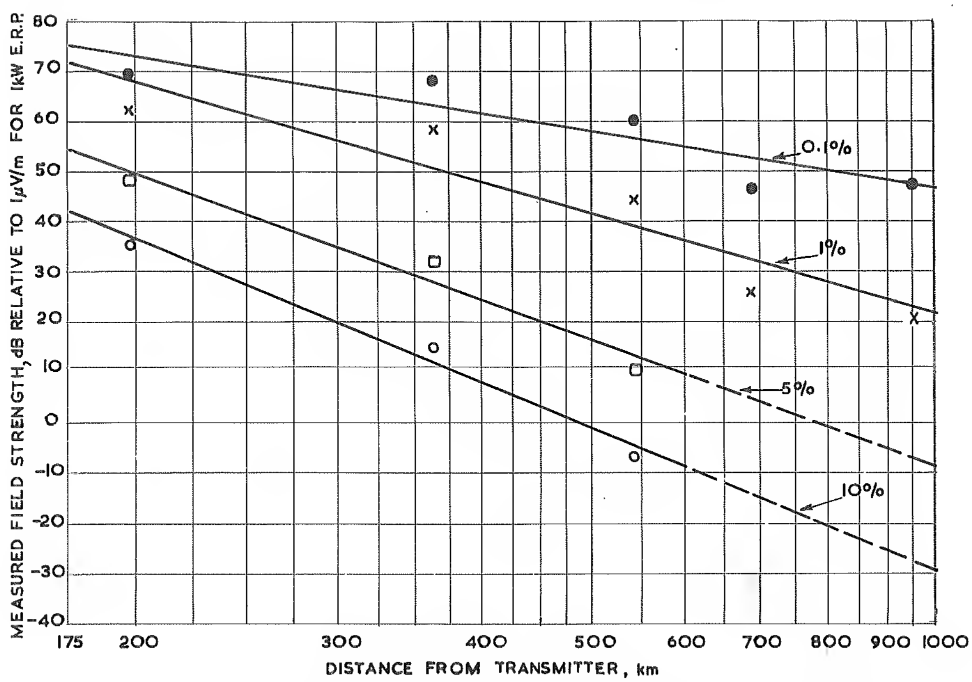

Fig. 5 - 560 Mc/s oversea: variation of measured field strength with distance for fixed percentages of the time

● 0·1%
× 1%
□ 5%
○ 10%

calculated by the least squares method, are drawn for selected percentage times. A power relationship is implied between field strength, E, and distance, d, of the form $E = K/d^m$. Values of m and 20 log K are given in Table 5 for the selected percentage times.

TABLE 5

PERCENTAGE TIME	m	20 log K
0·1%	+1·874	158·4
1%	+3·313	219·7
5%	+4·173	240·9
10%	+4·722	253·1

5. FIELD STRENGTH RECEIVED AT 50% LOCATIONS

5.1. Receiving Site Correction Factors

The field strengths measured at the receiving sites chosen for this experiment may not be representative of the field strengths received at the average re-

ceiving installations in the areas on the land round them. The results obtained may be more generally applicable if they relate to the field strengths received at 50% of the locations in the areas round the sites.

In earlier propagation measurements made over land paths[4] an approximation of the relation between the field strengths measured at a site and the field strengths received at 50% of the locations in the area round the site has been obtained by comparing the field strengths received at the site and at a number of spot points within 5 miles (8 km) of the site. The average of the ratio in decibels of the field strengths received at the spot points and at the fixed site was taken as the required relationship. This average has been called the site variation factor.

This method of obtaining a site variation factor was adopted to find a correction factor relating the field strengths measured at Happisburgh to the field strengths received at 50% of the locations on the land within 1 mile (1·6 km) of the Happisburgh site. The limiting radius of 1 mile (1·6 km) from the fixed site gave land paths of up to 4½ miles (7·2 km) in the direction of the transmitter. Correction factors were not obtained for the more distant sites, where signals were present only during abnormal propagation conditions.

The receiving sites chosen for this experiment are situated at various heights above mean sea level between 30 ft (9·1 m) and 300 ft (91 m) and are close to the coast line, with the exception of the Lerwick site, which is some 3000 ft (914·5 m) inland. Since even at the Lerwick site the ground tends to fall away in the direction of the transmitter, the effective heights of the receiving aerials will be of the order of their heights above mean sea level, while the effective receiving aerial height at the average receiving installation may be of the order of 30 ft (9·1 m). It was considered that the measured results would be more representative of the field strengths received at average receiving installations if they were related to the field strengths received at a common aerial height above mean sea level of 30 ft (9·1 m).

Measurements made at spot points located on open sites near the coast on transmissions from Scheveningen at 187 Mc/s indicated that, over a limited range of heights, doubling the height of the receiving aerial above mean sea level increased the median field strength by 3 dB. This implies a relationship between field strength, E, and height above mean sea level, h, of the form $E = kh^{1/2}$ where k is a constant. It was not practicable to obtain a relationship between field strength and receiving aerial height above sea level during the present experiment; measurements were restricted by receiver sensitivity to periods of abnormal propagation. It was considered that the field strength would increase with increasing receiving aerial height more rapidly at 560 Mc/s than at 187 Mc/s, and it was assumed that doubling the height of the receiving aerial above sea level would increase the field strength by 4 dB. This assumption leads to a relationship between field strength, E, and height above mean sea level, h, of the form $E = kh^{2/3}$. Correction factors calculated from this relationship are listed in Table 6.

Measurements of site variation factor in the Happisburgh area show that, at Happisburgh, the correction factor of -6 dB derived from this assumption has the same value as the site variation factor.

TABLE 6

Band IV Oversea:
Assumed Correction Factors to give
Field Strengths at 30 ft (9·1 m) a.m.s.l.

SITE	CORRECTION FACTOR (dB)
Happisburgh	-6
Flamborough Head	-11
Newton-by-the-Sea	-7
Bridge of Don	-4
Lerwick	-14

5.2. Measurements of Site Variation Factor in the Happisburgh Area

Recordings of field strength were made during May 1961 with mobile equipment at each of 13 sites in turn for periods of from one to three hours with a receiving aerial, a single Yagi, at 30 ft (9·1 m) a.g.l. The sites were chosen at random, but their locations were determined by considerations of accessibility with the mobile equipment and by the absence of local obstructions. Details of the locations of the sites are given in the Appendix, together with the median field strengths recorded and the appropriate median field strengths at the Happisburgh site. The average of the difference in decibels between the field strengths measured at the temporary and fixed sites (the site variation factor) is 6 dB, i.e. the Happisburgh site receives field strengths greater by 6 dB than the field strengths received at 50% of the locations in the area near the site.

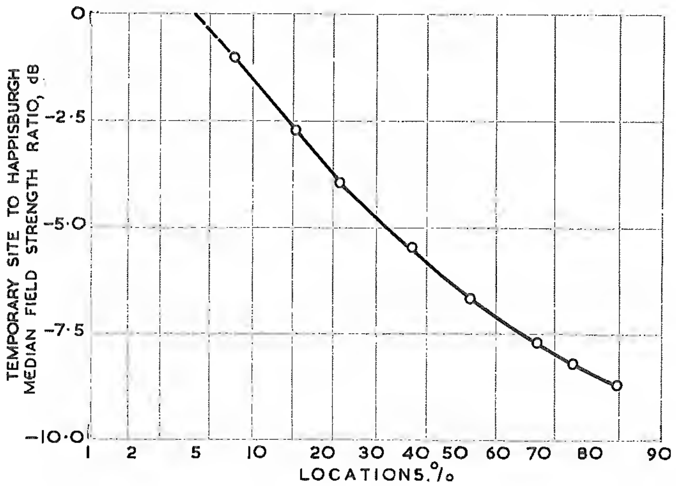

Fig. 6.- Happisburgh area: field strength ratio in dB related to percentage locations

The ratios in decibels of the median field strengths received at the temporary sites relative to the appropriate median field strengths recorded at the Happisburgh site are plotted in Fig. 6 against percentage locations. It is seen that the site at Happisburgh comes into the category of a '5% location'.

5.2.1. Variation of Happisburgh Site Variation Factor with Changing Propagation Conditions

There are indications that the ratio of the median field strengths received at the temporary sites and at the Happisburgh site is not a constant but depends upon propagation conditions. The ratios, in decibels, of the median field strengths

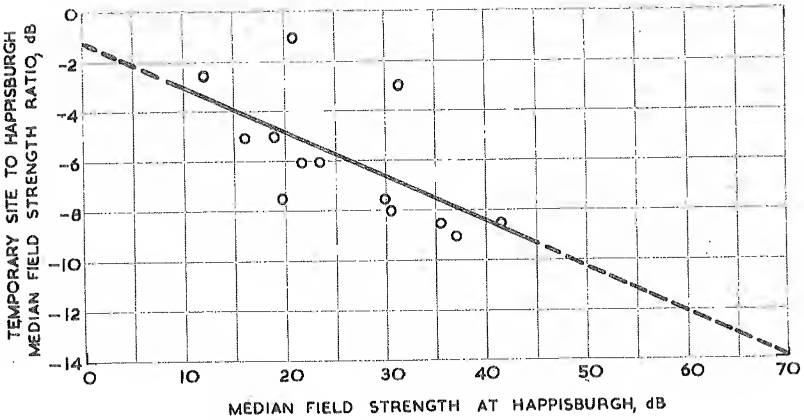

Fig. 7 - Happisburgh area: ratios of field strengths at temporary sites and Happisburgh related to median field strength at Happisburgh

recorded at the temporary sites and at Happisburgh have been plotted in Fig. 7 against the appropriate median field strengths recorded at the Happisburgh site. A line of 'best fit', calculated by the method of least squares, is drawn through the points and indicates that the differences between median field strengths at the temporary sites and at Happisburgh are likely to increase as the field strength at Happisburgh increases. The correlation coefficient, calculated from the measurements, is 0·64. From tables of significance this gives a probability of 0·98 to the hypothesis that the relationship is significant. This relationship is thought to be a function of the difference between the effective receiving aerial heights at the temporary sites and at the Happisburgh site.

Since the terrain near Happisburgh is either flat or gently undulating, the effective heights of the receiving aerial at the temporary sites will not deviate substantially from the actual height of 30 ft (9·1 m), and shadow losses will remain small. The Happisburgh site is located near the top of a 50 ft (15 m) cliff and its receiving aerial has an effective height of the order of 80 ft (24 m). It may be inferred that the smoothed curve in Fig. 7 is a plot of the difference between the median field strengths received with an aerial having an effective height of 30 ft (9·1 m) and those received with an aerial of effective height 80 ft (24 m), against the median field strength received at the greater effective height.

The relationship in Fig. 7 implies that the Happisburgh site variation factor will become increasingly negative as tropospheric conditions leading to abnormal propagation are enhanced. The field strengths received at Happisburgh for the different percentages of the time are compared in Table 7 with the field strengths at the average location in the area, using the differences indicated in Fig. 7.

TABLE 7

Happisburgh - 560 Mc/s Field Strength at 50% Locations

PERCENTAGE TIME	FIELD STRENGTH AT HAPPISBURGH SITE (dB rel. 1 μV/m FOR 1 kW e.r.p.)	SITE VARIATION FACTOR (FROM FIG. 7) dB	FIELD STRENGTH AT 50% LOCATIONS WITHIN 1 MILE (1·6 km) OF HAPPISBURGH SITE (dB rel. 1 μV/m FOR 1 kW e.r.p.)
1	62·0	-12·5	49·5
5	47·5	-10·0	37·5
10	35·0	-7·5	27·5
50	7·0	-2·5	4·5

The field strengths received at the average locations in the area for 1% of the time may be of the order of 12 dB below the field strengths received at the Happisburgh site.

5.3. Corrected Field Strength versus Distance Curves

The corrections derived in Section 5.1. have been added to the field strengths derived from Fig. 2 for selected percentage times. The corrected results are set forth in Table 8.

TABLE 8

Band IV Oversea:
Field Strength for a Receiving Aerial Height of 30 ft (9·1 m) a.m.s.l.

SITE	DISTANCE FROM TRANSMITTER (km)	FIELD STRENGTH IN dB rel. 1 μV/m FOR 1 kW e.r.p.		
		1%	5%	10%
Happisburgh	198	56·0	41·5	29·0
Flamborough Head	365	47·0	20·5	3·0
Newton-by-the-Sea	543	37·0	3·0	-14·0
Bridge of Don	690	21·0	N.L.	N.L.
Lerwick	950	7·0	N.L.	N.L.

N.L. - Signal did not exceed receiver noise level for the appropriate percentage time.

These corrected field strengths listed in Table 8 are plotted in Fig. 8 on a logarithmic distance scale. Lines of best fit, calculated by the least squares method, have been drawn through the points. Values of m and 20 log K are given in Table 9.

TABLE 9

Band IV Oversea:
Corrected Field Strength versus Distance Parameters

PERCENTAGE TIME	m	20 log K
1%	-3·584	225·8
5%	-4·357	242·2
10%	-4·906	254·4

5.4. Comparison of Corrected Field Strength versus Distance Curves with CCIR Curves

The field strength/distance curves derived in Section 5.3. for receiving aerial heights of 30 ft (9·1 m) have been re-drawn in Fig. 9, together with the

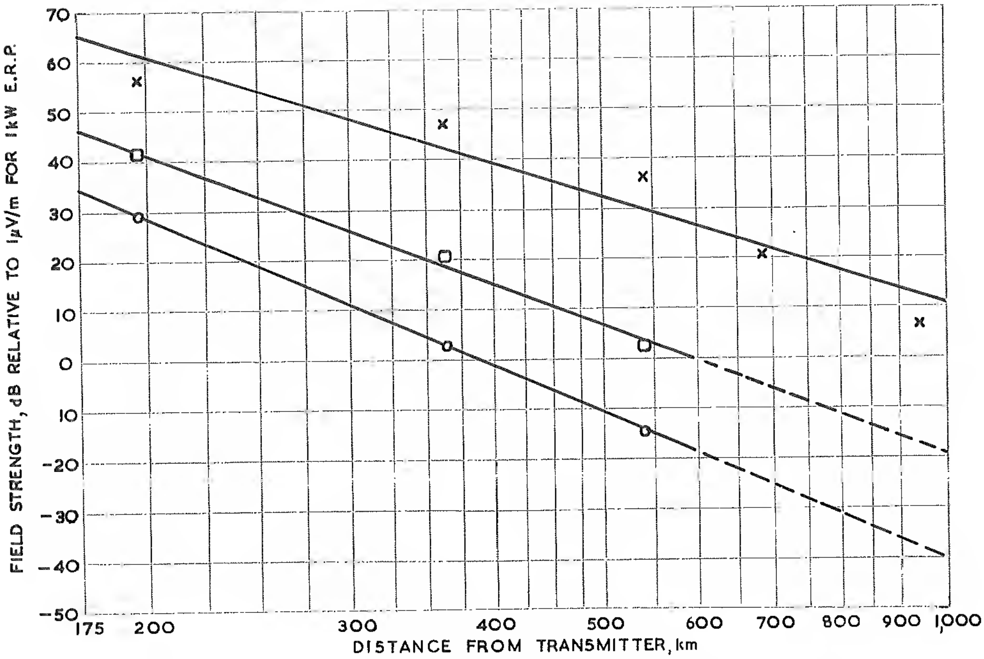

Fig. 8 - 560 Mc/s oversea: variation of field strength at 30 ft (9·1 m) a.m.s.l. with distance for fixed percentage times

× 1%

□ 5%

○ 10%

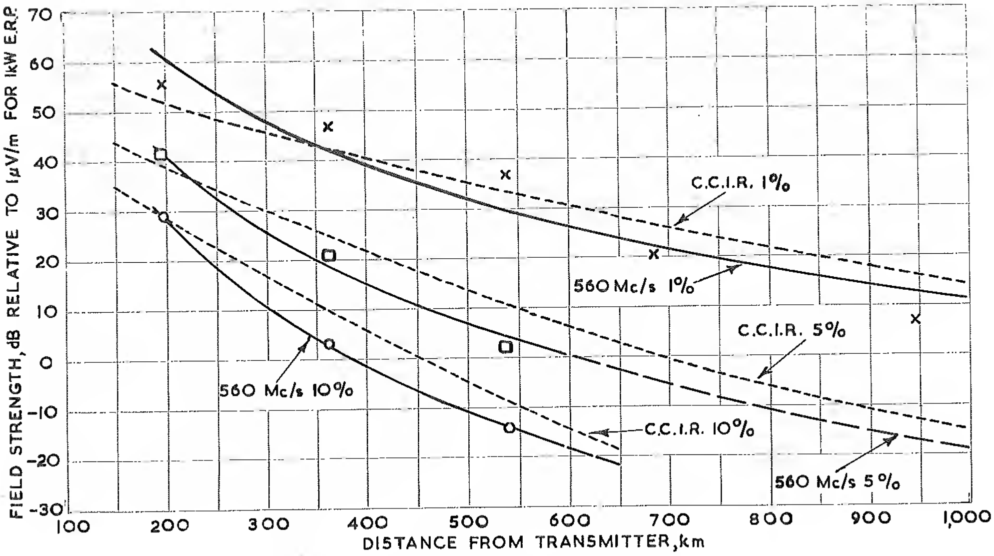

Fig. 9 - Comparison of field strength/distance curves 560 Mc/s oversea field strength at 30 ft (9·1 m) a.m.s.l. with CCIR (Cannes 1961)

tropospheric propagation curves for Bands IV/V over sea paths published by the CCIR[5] for the Stockholm Conference in 1961. The CCIR curves are for a transmitting aerial height of 300 m, but it is stated that: 'The field strengths exceeded for small percentages of the time are not expected to be sensitive to appreciable changes in the transmitting aerial height'.

There is reasonable agreement between the curves. The maximum differences occur at about 400 km when the 560 Mc/s curves for 5% and 10% time are lower than the CCIR curves by 7 dB.

6. COMPARISON OF BAND IV OVERSEA RESULTS WITH THE RESULTS OF EARLIER EXPERIMENTS

6.1. Comparison Over the Same Sea Paths

Field strengths exceeded for certain selected percentages of the time, taken from the measurements[2] on transmissions from Scheveningen made at 187 Mc/s and 560 Mc/s are listed in Table 10, together with their differences.

TABLE 10

Measured Results: 187 Mc/s and 560 Mc/s

SITE	DISTANCE (km)	FREQUENCY	FIELD STRENGTH rel. 1 μV/m FOR 1 kW e.r.p.			560 Mc/s FIELD STRENGTH rel. 187 Mc/s FIELD STRENGTH (dB)		
			0·1%	1%	10%	0·1%	1%	10%
Happisburgh	198	187 Mc/s	54·0	43·0	28·0			
		560 Mc/s	69·0	62·0	35·0	15·0	19·0	7·0
Flamborough Head	365	187 Mc/s	50·0	26·5	9·0			
		560 Mc/s	67·5	58·0	14·0	17·5	31·5	5·0
Newton-by-the-Sea	543	187 Mc/s	37·0*	10·0	-18·0*			
		560 Mc/s	60·0	44·0	-7·0*	23·0	34·0	11·0
Bridge of Don	690	187 Mc/s	27·5	1·0	N.L.			
		560 Mc/s	46·0	25·0	N.L.	18·5	24·0	-
Lerwick	950	187 Mc/s	22·0	-11·0	N.L.			
		560 Mc/s	47·0	21·0	N.L.	25·0	32·0	-

*Extrapolated result. N.L. - noise level.

It is seen that signals in Band IV are propagated with considerably less attenuation than those in Band III, especially for 0·1% and 1% of the time, when the difference between measurements ranged from 15 dB to 34 dB. It must be noted, however, that measurements on the two transmissions were made over different periods.

The analyses of measurements made at Happisburgh and Newton-by-the-Sea on transmissions from Scheveningen on 94·35 Mc/s, 187 Mc/s and 560 Mc/s are shown, in Fig. 10 and Fig. 11 respectively, plotted as field strength against percentage valid recording time. The enhanced propagation on 560 Mc/s for the lower percentage times is clearly shown and suggests that another mode of propagation, such as 'ducting', is becoming more effective with increasing frequency.

It is of interest to note that, at Happisburgh, for percentages of the time in excess of 30%, the 560 Mc/s field strengths are from 6 dB to 7 dB below those recorded on 187 Mc/s. Earlier measurements[6] made over land paths indicated that signals are propagated with less attenuation in Band III than in Band IV over long distances. This suggests that the more effective mode of propagation of Band IV over sea paths is present for relatively low percentages of the time.

6.2. Comparison with Band IV Overland Results

The field strength/distance curves derived in Section 5.3. for a receiving aerial height of 30 ft (9·1 m) have been plotted in Fig. 12, together with the field strength/distance curves[6] derived from the Band IV overland measurements and including receiving site variation factor corrections.

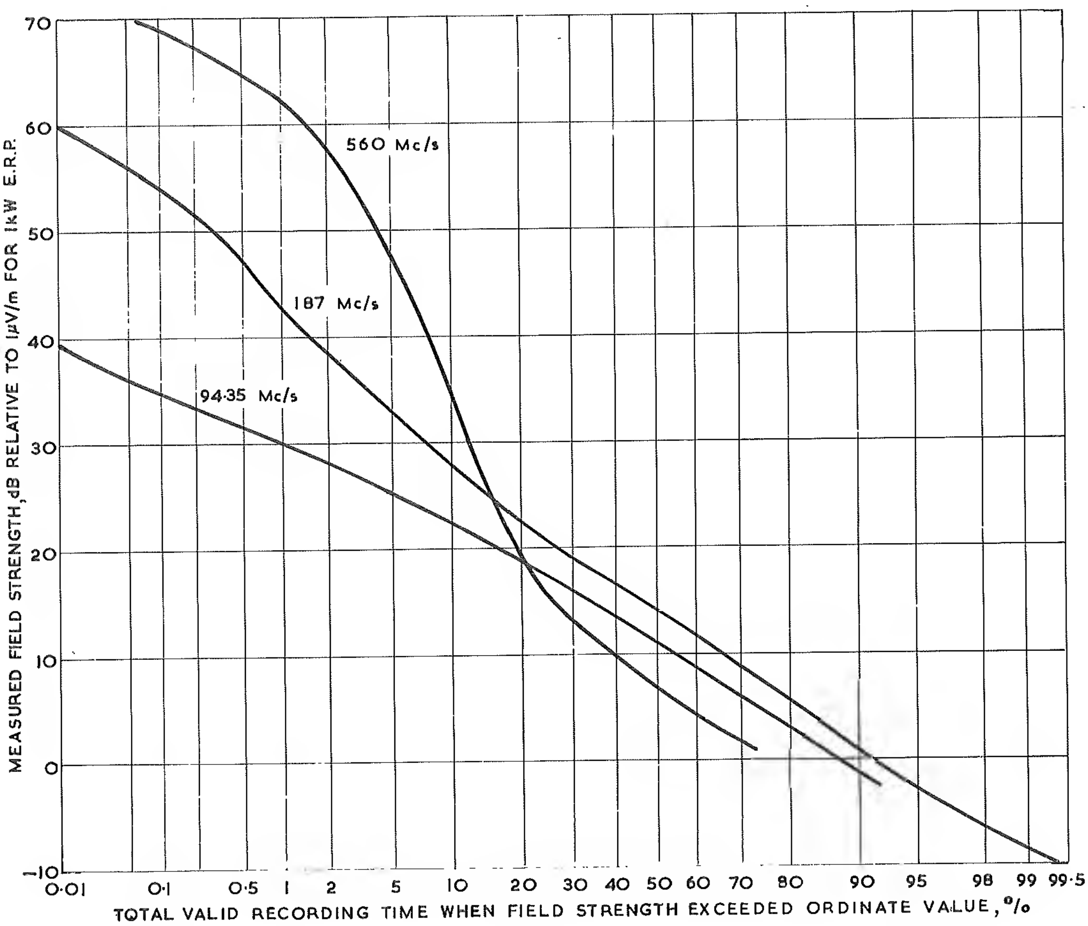

Fig. 10 - Comparison of field strength/percentage time curves recorded at Happisburgh on 94·35 Mc/s, 187 Mc/s, 560 Mc/s

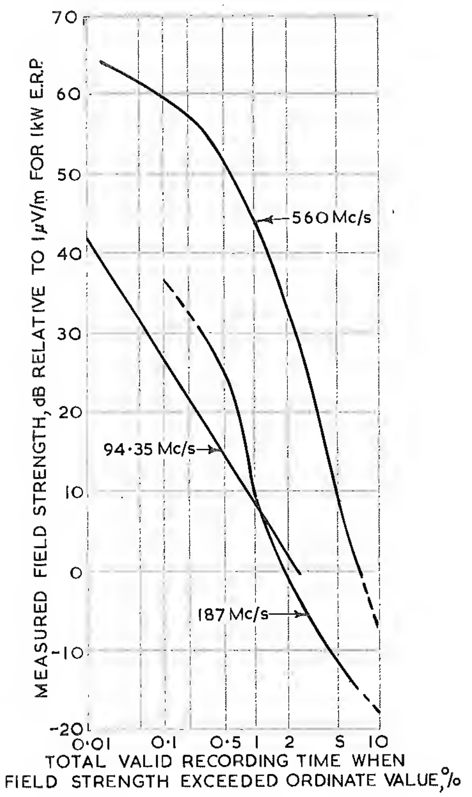

Fig. 11 - Comparison of field strength/percentage time curves recorded at Newton-by-the-Sea on 94·35 Mc/s, 187 Mc/s, 560 Mc/s

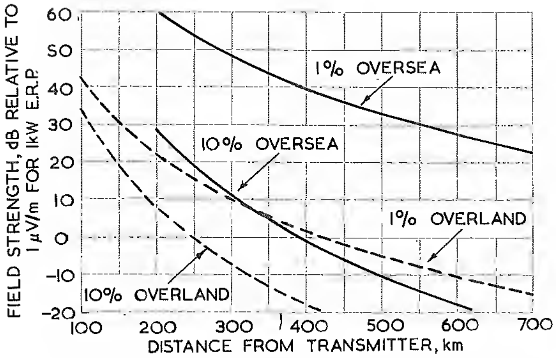

Fig. 12 - Comparison of overland and oversea field strength/distance curves for Band IV

Attenuation over sea paths is appreciably less than over land paths for the low percentage of the time considered. The separation between the 10% curves is of the order of 18 dB, while the 1% curves are more than 30 dB apart.

7. CONCLUSIONS

For low percentages of the time the attenuation of signals is considerably less in Band IV than in Band III over long sea paths. In Band IV there is also considerably less attenuation over sea than over land paths. Band IV field strengths of the order of free space fields are exceeded on occasion at distances up to 950 km over sea paths.

Abnormal propagation occurred most frequently during the first four months of the experiment, especially over the longer transmission paths. A seasonal trend is indicated, abnormal propagation tending to occur mainly during the summer months. The prolonged summer of 1959 may have led to a bias in the overall results but stable anticyclonic conditions favourable for tropospheric propagation could become established during any summer, although anticyclonic conditions lasting as long as in 1959 are rather unlikely to occur once in every two years off the east coast of Great Britain.

The seasonal trend of occurrence of abnormal propagation has to be considered when planning co-channel transmitters. If a field strength level is derived from the overall results, with which interference may be expected for a certain percentage of the time, this percentage may be appreciably exceeded during the summer months.

Measurements of site variation factor made within 1 mile (1·6 km) of the Happisburgh site indicate that the difference between the field strengths received at Happisburgh and at temporary sites depends on the degree of abnormal propagation present.

8. ACKNOWLEDGEMENTS

The BBC acknowledges with grateful thanks the facilities most willingly provided by the Netherlands Postal and Telecommunications Services, and, in particular, by the staff of Scheveningen Radio who were responsible for installing and maintaining the transmitting system.

Thanks are also due for the assistance and facilities given by the Superintendent Meteorological Officer and technical staff at Lerwick Observatory. Acknowledgement is also made to the Ministry of Transport for permission to use its coastguard stations as receiving sites and to the unfailing help given by the coastguard officers.

The Research Department staff concerned with the erection and maintenance of the apparatus were Messrs. S.J. Ashdown and I. Rhodes, who, with Mrs. P.A. Gagan, also carried out the analysis of the data.

9. REFERENCES

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APPENDIX

Site Variation Factor Measurements at Happisburgh on Transmissions from Scheveningen on 560 Mc/s

GRID REFERENCE (TG)	SITE HEIGHT a.m.s.l.		DISTANCE FROM FIXED SITE		DISTANCE FROM COAST IN DIRECTION OF TRANSMITTER		FIELD STRENGTH AT FIXED SITE	FIELD STRENGTH AT TEMPORARY SITE	TEMPORARY/FIXED FIELD STRENGTH RATIO
	ft	m	miles	km	miles	km	dB	dB	dB
388307	30	9	0·9	1·4	On coast		19·0	14·0	-5·0
384310	40	12	0·6	1·0	On coast		31·5	28·5	-3·0
384310	10	3	0·6	1·0	On coast		23·5	17·5	-6·0
357331	30	9	0·7	1·1	On coast		35·5	27·0	-8·5
367318	40	12	0·6	1·0	1·3	2·1	37·0	28·0	-9·0
373312	40	12	0·4	0·6	1·7	2·7	41·5	33·0	-8·5
367305	30	9	1·0	1·6	4·5	7·2	30·5	22·5	-8·0
366311	40	12	0·7	1·1	3·2	5·2	16·0	11·0	-5·0
378303	40	12	0·9	1·4	2·9	4·7	12·0	9·5	-2·5
375312	40	12	0·3	0·5	1·4	2·3	19·5	12·0	-7·5
384304	30	9	0·9	1·4	1·5	2·4	21·5	15·5	-6·0
376307	40	12	0·6	1·0	2·2	3·5	30·0	22·5	-7·5
367313	50	15	0·7	1·1	2·4	3·9	21·0	20·0	-1·0
								Average	-6·0 dB

Happisburgh site height 50 ft (15 m) a.m.s.l.

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